The first two years of operation of a semi-industrial AnMBR plant for urban wastewater treatment


* CALAGUA – Unidad Mixta UV-UPV, Departament d’Enginyeria Química, Universitat de València, Spain (e-mail: angel.robles@uv.es; josep.ribes@uv.es; aurora.seco@uv.es).
** FCC Aqualia, S.A., Spain (e-mail: franciscojose.garcia@fcc.es; freddy.duran@fcc.es; jvazquezp@fcc.es; FRogalla@fcc.es).
*** CALAGUA – Unidad Mixta UV-UPV, Institut Universitari d’Investigació d’Enginyeria de l’Aigua i Medi Ambient – IIAMA, Universitat Politècnica de Valencia, Spain (e-mail: anjibe1@upvnet.upv.es; jserralt@hma.upv.es; jferrer@hma.upv.es).

Abstract: In order to demonstrate the potential of AnMBR technology for urban wastewater (UWW) treatment, a semi-industrial AnMBR plant has been operated for more than 2 years with effluent from the pre-treatment of a full-scale WWTP located in Alcázar de San Juan (Ciudad Real, Spain). The plant mainly consists of an anaerobic reactor of 40 m³ connected to a filtration system with a total membrane area of 123 m². COD removal remained around 90%. Sustained fluxes of above 15 LMH were set while membrane chemical cleaning frequency remained below once per year. Sewage treatment with net energy production was feasible while obtaining high quality water optimal for reuse.

Keywords: Anaerobic Membrane BioReactor (AnMBR); semi-industrial scale; urban wastewater.

Session: Anaerobic MBR, research & application

Introduction

AnMBR technology can be used for organic matter removal from low-loaded wastewater at ambient temperatures. This new approach is focused on a more sustainable concept, where urban wastewater (UWW) turns into a source of energy and nutrients whilst producing a recyclable water resource (Pretel et al., 2016). AnMBR technology will contribute to a net decrease in the carbon footprint of wastewater treatment, since it will reduce drastically CO₂ emissions by avoiding oxidation and producing methane as energy carrier.

This study shows the results from the first two years of operation of a semi-industrial AnMBR for UWW treatment within the LIFE MEMORY project framework (http://www.life-memory.eu/en/). The aim of LIFE MEMORY project is to demonstrate the viability of a new technological concept for UWW treatment and resource recovery based on AnMBR, taking a further step in the development of this technology by scaling-up the installation size in order to reach full scale.

Material and Methods

The LIFE MEMORY project operates an AnMBR plant that mainly consists of an anaerobic reactor of 40 m³ (34.4 m³ working volume) connected to three membrane tanks of 0.8 m³ each (0.7 m³ working volume) with a total filtration area of 123 m². The AnMBR uses industrial scale hollow-fiber membranes (PURON® PSH41, 0.03-µm pore size, total filtration area of 41 m²) and is fed with UWW coming from the pre-treatment step of a full-scale WWTP. Figure 1
shows a general view and the flow diagram of the AnMBR plant. Table 1 shows the average characteristics of the influent to the anaerobic reactor, which is characterized by a strong load variability.

During more than two years of continuous operation, the plant has been run at hydraulic retention times (HRTs) from 40 to 24 hours, sludge retention time of 70 days, and ambient temperature ranging from 10 to 30°C. Regarding the filtration process, 20°C-standardized transmembrane fluxes ($J_{20}$) from 15 to 25 LMH were applied.

**Results and Discussion**

The AnMBR plant was started up on September 2016. Around day 100, both the COD and the TS concentration of the mixed liquor reached a plateau, indicating the vicinity of a pseudo-steady state operation, despite the strong variability of the influent.

As Figure 2 shows, despite the high dynamics in the influent COD ($COD_{in}$), the COD removal efficiency remained around 90%, while effluent COD concentration remained below the COD discharge limit. Sludge production varied between 0.1 and 0.2 kg VSS·kg$^{-1}$ $COD_{in}$ in average, depending on operating conditions. These results represents a reduction between 75 and 45% in sludge production, compared to the 0.43 kg VSS·kg$^{-1}$ $COD_{in}$ that would have been produced aerobically.

Regarding the physical separation process, Figure 3 shows the evolution during the experimental period of the transmembrane pressure (TMP), $J_{20}$, the 20°C-standardized membrane permeability ($K_{20}$), the mixed liquor total solids (MLTS) concentration, and SGD$_P$. As this figure shows, $J_{20}$ was set to values from approx. 15 to 25 LMH even at low SGD$_P$. Indeed, no chemical cleaning of the membranes was conducted for almost one year of continuous operation at $J_{20}$ above 20 LMH, while the specific gas sparging demand per volume of permeate (SGD$_P$) was around 10 to 14 Nm$^3$/m$^3$ (see first year of operation in Figure 3).

The energy balance results revealed that AnMBR appears as a net energy producer, reducing the energy demand of the sewage treatment field when compared to aerobic processes. Considering the recovery of dissolved methane in the effluent, an additional energy production of up to 0.10 kWh per m$^3$ of treated water is feasible (degassing membranes were used for capturing the methane dissolved in permeate). LCA results showed that AnMBR presents a reduced GWP impact compared to aerobic processes, mainly due to the reduction in energy demand. Similar results to the ones obtained within GWP are obtained for other impact categories such as abiotic depletion.

Hence, AnMBR technology would drive circular economy in the future, being its potential boosted when combined with sewer mining and source separation.

**Acknowledgements**

This research work was possible thanks to co-finance of the European financial instrument for the Environment (LIFE+) during the implementation of the Project Membrane for ENERGY and WATER RECOVERY “MEMORY” (LIFE13 ENV/ES/001353).

**References**

Pretel, R., Robles, A., Ruano, M.V., Seco, A., Ferrer, J. 2016 Economic and environmental sustainability of submerged anaerobic MBR-based (AnMBR-based) technology as compared to aerobic-based technologies for moderate-/high-loaded urban wastewater treatment. *Journal of Environmental Management* 166, 45-54
Figure 1. (a) General view and (b) flow diagram of the AnMBR plant.

Figure 2. Evolution of total COD (in the influent and the effluent), COD removal efficiency and temperature in the system.

Figure 3. Evolution of: (a) TMP, K_{20} and J_{20}; and (b) SGD_{20}, MLSS and J_{20}. 
Table 1. Average influent wastewater characteristics.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>mg TSS·L⁻¹</td>
<td>534 ± 254</td>
</tr>
<tr>
<td>Total COD</td>
<td>mg COD·L⁻¹</td>
<td>1218 ± 416</td>
</tr>
<tr>
<td>BOD₅</td>
<td>mg COD·L⁻¹</td>
<td>688 ± 269</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>mg N·L⁻¹</td>
<td>56.3 ± 16.7</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>mg P·L⁻¹</td>
<td>10.1 ± 3.1</td>
</tr>
<tr>
<td>Sulphate</td>
<td>mg SO₄·S·L⁻¹</td>
<td>162 ± 32</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>mg CaCO₃·L⁻¹</td>
<td>610 ± 123</td>
</tr>
<tr>
<td>VFA</td>
<td>mg COD·L⁻¹</td>
<td>116 ± 92</td>
</tr>
</tbody>
</table>